(12) UK Patent Application (19) GB (11) 2 310 822 (13) A

(43) Date of A Publication 10.09.1997

(21) Application No 9704535.5

(22) Date of Filing 05.03.1997

(30) Priority Data
(31) 9604892 (32) 07.03.1996 (33) GB

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(51) INT CL^6
B29C 70/30 43/12 43/20 43/52 43/56 51/08 51/14 51/18

(52) UK CL (Edition O)
B5A AT1P A1R214D A1R214E A1R214F A1R214H A1R314C1A A1R314C1C A1R314C6 A1R420 A1R422 A2A1 A2A4A A2A4B A2A4F A2E12A A2E12C A2H5 A2L

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WO 94/16870 A1 US 4906172 A US 3886248 A
WPI Abstract Accession No. 85-200770 & JP60127148A (MATSUSHITA) 06.07.85 (see abstract)

(58) Field of Search
UK CL (Edition O) B5A AT1P , B5N
INT CL^6 B29C 43/12 43/20 43/52 43/56 51/08 51/14 51/18 70/30
Online: WPI

(54) Moulding a structure from thermoplastics material

(57) A method of moulding a thermoplastics composite structure, comprises laying-up a thermoplastic fabric 30 in a mould 28, applying pressure to the lay-up and maintaining pressure on the lay-up during: heating the lay-up to over the melting temperature of the thermoplastic; holding the lay-up for a holding period over the melting temperature; and cooling the lay-up to solidify the thermoplastic. Various methods are disclosed for supporting the thermoplastic fabric within the mould tool before the pressure is applied, and for heating the lay-up or the region of the mould tool adjacent the lay-up.

The fabrics comprise filaments of a thermoplastic material (e.g. polypropylene or nylon) interspersed or interwoven with reinforcing fibres such as glass, aramids, carbon or boron. Heat may be applied directly to the thermoplastic composite material by applying heater mats or by incorporating, in the material, radiation-absorbent fillers which respond to infra-red, microwave or radio frequency heating. Induction heating may be employed.

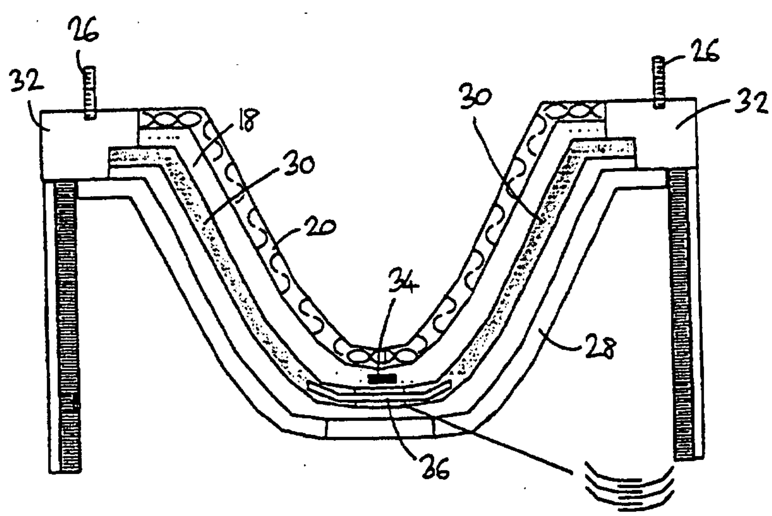

FIGURE 2

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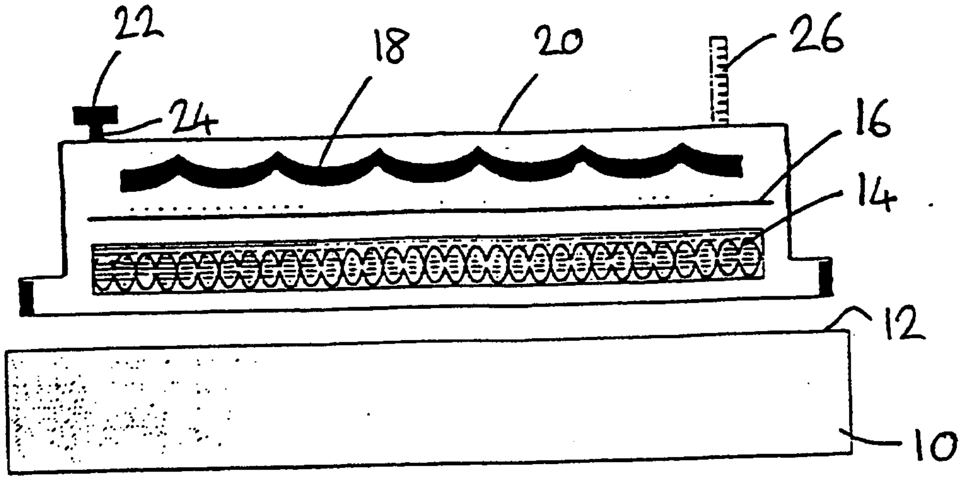


FIGURE 1

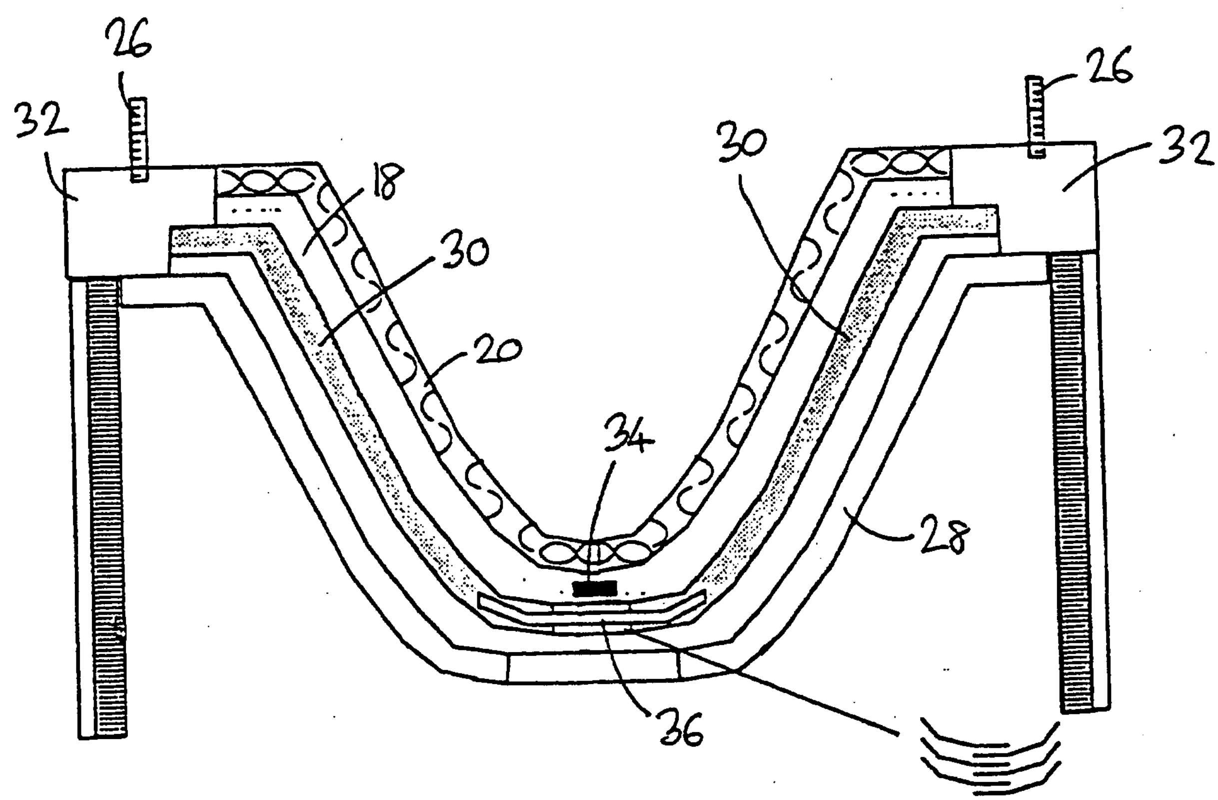


FIGURE 2

FIGURE 3

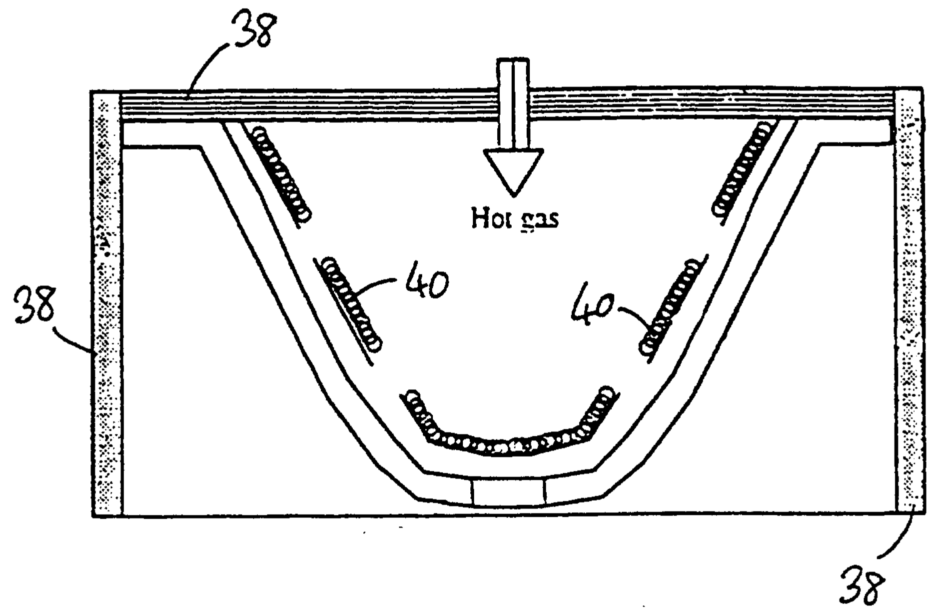


FIGURE 4

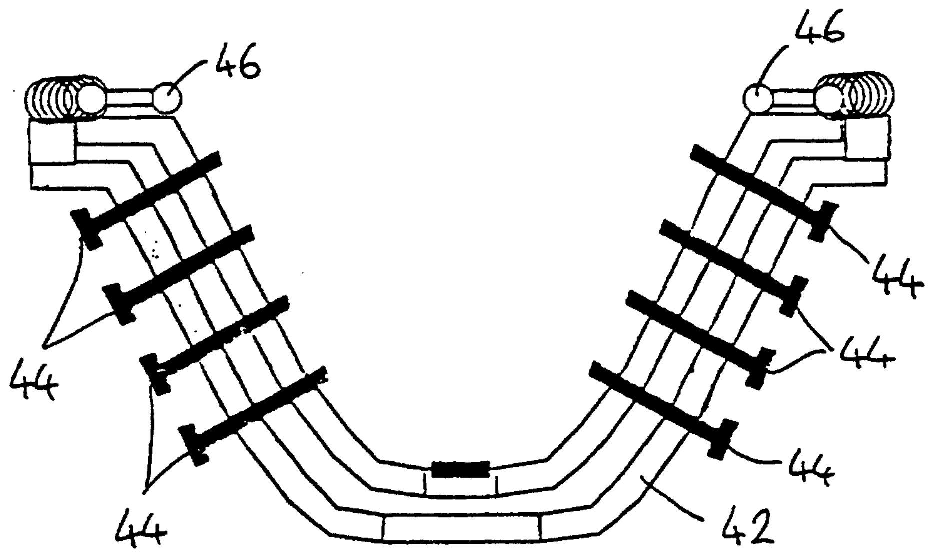
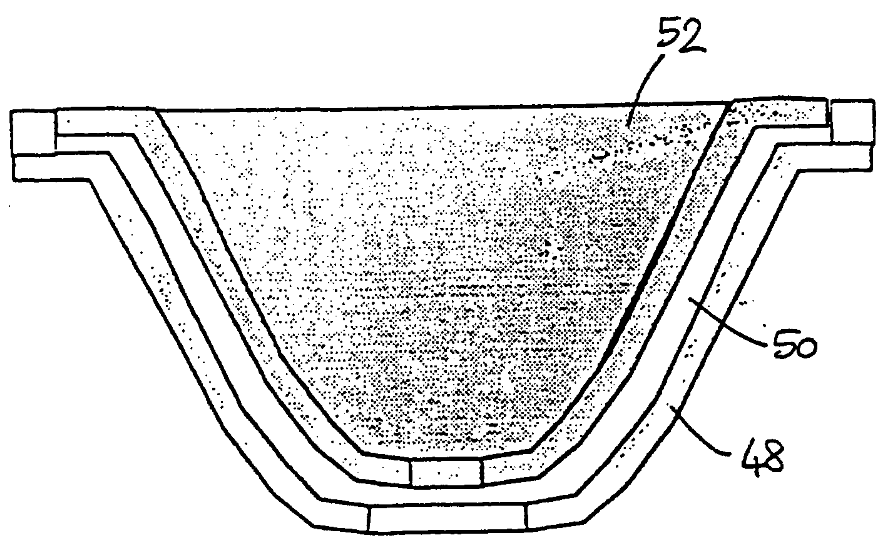


FIGURE 5



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THERMOPLASTIC AND THERMOPLASTIC COMPOSITE STRUCTURES AND METHODS OF MANUFACTURING THEM

This invention relates to thermoplastic and thermoplastic composite structures, particularly large-scale structures such as boat hulls, other marine structures and products, and storage tanks. Aspects of the invention relate to materials and techniques used in the manufacture of thermoplastic composite structures.

Most structural composite components manufactured today are based upon thermosetting composite materials, i.e. composite materials comprising thermosetting resins such as polyester, vinylester and epoxy. Indeed, approximately 90% of all currently-used advanced composite materials employ thermosetting resins.

The most common thermosetting composites employ glass fibre reinforcements embedded in a resin matrix. The glass fibres come in many grades (e.g. E-glass, R-glass, D-glass, S-glass, AR-glass, RH-glass) and several configurations such as uni-directional mat and chopped strand mat. Higher-performance fibre reinforcements such as carbon (low-, intermediate- and high-modulus grades), aramids (e.g. as sold under the trade mark Kevlar), boron and ceramics are used in applications where the demands of use justify the relatively high cost of such materials.

The art of thermosetting composites dates back several decades, during which time many techniques have been developed for manufacturing components using thermosetting resins. These techniques include resin transfer moulding (RTM), pultrusion, autoclaving, and contact moulding.

Large-scale composite components such as boat hulls have traditionally been produced by manual lay-up methods in which materials are positioned by hand in a mould or on a former. Usually, following the application of a release agent to the inner surface of a mould, a gel coat is applied and is followed by sheets and strips of reinforcement material, such as glass-fibre mat, which are soaked with solvent-based (e.g. styrene-

based) thermosetting resins and may be built up in layers.

The hand lay-up process is well-understood and the technology proven, thereby easing the certification of new boat designs. Most importantly, as the mould need not perform at elevated temperatures or under pressure, the capital cost of tooling is minimised; thus, manual lay-up is popular for small production runs. Further, manual lay-up is suitable for very large components, being constrained only by the size of the mould.

Unfortunately, the manual lay-up process is highly labour-intensive, requiring skilled or semi-skilled labour, and suffers from lengthy cycle times which militate against cost-effective mass production. The typical cycle time for moulding the hull of a five-metre craft, including lay-up and curing, is as long as five days. These problems do not matter greatly in small-scale production, being largely offset by the low tooling cost, but, increasingly, environmental disadvantages are coming to the fore.

The solvents used in thermosetting plastics are noxious and flammable, and increasingly stringent health and safety regulations will govern the storage and handling of the raw materials. For example, under proposed European legislation, the present limit on solvent (styrene) emissions of 100 parts per million will be reduced by at least a half and possibly by three-quarters.

The essentially open and accessible nature of the moulds and formers used in manual lay-up, and their often large surface area, makes it difficult to prevent solvent fumes from breaching the allowable limit. Accordingly, meeting the latest regulations will involve heavy capital expenditure on powerful extractors and so on, which unfavourably alters the economics of the process and may make the use of thermosetting plastics unfeasible for many applications. The economics of the process are further hindered by the need for specialised storage of the raw materials, which may include facilities for refrigeration of the solvents to maximise their limited shelf life.

Another environmental issue is disposal and recycling; thermosetting plastics defy efficient recycling and are difficult to break down for disposal.

Thermosetting composite materials also tend to suffer from performance drawbacks, notably blistering, delamination and crazing of gel coats, often due to osmotic effects, and poor abrasion/impact resistance due to brittleness of the matrix. Further, thermosetting materials are difficult to join once formed, without relying on mechanical fixings of some kind.

In an effort to avoid the disadvantages of thermosetting composite materials, the present invention contemplates the use of fibre-reinforced thermoplastic composite fabrics. These fabrics comprise filaments of a thermoplastic material (such as polypropylene or nylon) interspersed or interwoven with reinforcing fibres such as glass, aramids, carbon or boron.

Our research has found that interwoven or interdispersed thermoplastic composite fabrics drape well but, once heated to melt the thermoplastic filaments, may be shaped under minimal pressure, from 1 to 10 bar and typically from 2 to 5 bar, quickly to form a rigid fibre-reinforced component. The component has good mechanical performance, can be readily recycled (as can the raw materials), and can be readily joined using simple welding techniques. Thus, thermoplastic composite technology promises a rapid-cycle manufacturing process in which fabric is transformed into a useful rigid component without giving off troublesome fumes.

Thermoplastic composite fabrics are substantially inert, easy to handle, and easy to store. The raw material is self-contained and so does not require two parts - i.e. a resin and a reinforcement - to be sourced separately and brought together during manufacture. Thus, the chemical composition of the material is determined when the material is manufactured, and is not subject to change when the material is formed into a component.

A specific aspect of the invention contemplates the application of thermoplastic composite technology to large surface area mouldings as used, for example, in the marine industry. Thus, the invention encompasses boats and other vessels having a structure of thermoplastic composites, and the use of thermoplastic composites in the

manufacture of boats and other vessels.

Certain advantages of thermoplastic composites are of particular relevance to the marine industry. Specifically, the technology promises cycle times as short as four to eight hours for a five-metre boat hull, maximised fibre volume fraction, moulded-in inserts, minimal wastage, excellent homogeneity and consistency, improved salt water resistance, reduced blistering, increased toughness and higher resistance to impact and abrasion.

Another aspect of the invention contemplates various manufacturing techniques whereby components may be made more efficiently from thermoplastic composite materials.

For example, sections may be cut from thermoplastic fabrics and joined together or folded into a desired three-dimensional preform shape. Joining may be performed before the fabric is placed into a mould, to make a pre-form, or may be performed during moulding, sheets of the thermoplastic fabric having been overlapped (generally by at least 50 mm) during the lay-up process.

Cutting techniques include the use of mechanical shears, knives and ultrasonic blades to cut, slit or stamp the material into various lengths or shapes.

Joining techniques include stitching, welding and the use of adhesives. If stitching is employed, the stitch material can be a reinforcing fibre, which will enhance the z-axis properties of the material if appropriately aligned, or a thermoplastic filament, which melts under further processing and forms a weld. At the joins between sections of material, the edges of the material can be tapered and the tapered portions overlapped, with stitching passing through the overlapped portions.

The fabric can simply be draped over a mould tool and the excess cut away, or may be cut to the required shape.

As thermoplastic composite fabrics are non-tacky or 'dry', the invention contemplates various positioning and handling techniques to position and hold the material in a mould

during a processing cycle, before pressure is exerted on the lay-up. Correct positioning is vital to obtain components of the desired shape, and correct orientation of the material is essential if the reinforcements are aligned, conferring anisotropic properties on the material.

Whilst thermoplastic fabric can simply be draped over a male mould tool, a steep-sided or complex-shaped female tool usually demands positioning and locating techniques such as those set out below.

(i) Sheets of the fabric can be heated to their processing temperature and presented to the tool so that the material takes on the shape of the tool and is located thereby. The material can then be formed into shape with a press or by a vacuum.

(ii) A sheet of the fabric can simply be allowed to slump into a mould under gravity but, to avoid kinking during this process, tension on the sheet is maintained as it slumps, e.g. by means of a frame carrying tensioned rollers which grip the material around the flanged edges of the mould but enable the material to move, or flow, during the processing cycle.

(iii) A clamp frame can be used to clamp an edge of a thermoplastic sheet to an upper side edge of a mould, the sheet being simply draped into the tool once clamped and being overlapped at its lower edge with a corresponding sheet clamped to, and draped in from, the other side of the mould.

(iv) The fabric can be locally tacked to other fabric layers or to the surface of the mould tool, for example by means of a hot air gun to melt regions of the material, optionally after sprinkling the contact surface of the fabric with a 1-2% thermosetting polymer powder to enhance its adhesion with the mould tool.

(v) The material can be mechanically located by means of pins of plastics, ceramics or metal, which protrude from the mould surface to engage the material and may be retractable into the mould or detachable from the mould. If the latter, the pins may be

made of plastics to be moulded in to the component.

(vi) The material can be pre-formed so that it closely fits the mould or former and so is held efficiently by friction with the mould surface.

(vii) Adhesive tapes of thermosetting or thermoplastic material can be employed to hold the sheet in the desired position with respect to the mould tool.

(viii) The fabric and the tool can be electrically charged (preferably by applying a charge to the tool which induces a charge in the fabric) whereby electrostatic attraction holds the fabric to the mould surface.

(ix) air can be evacuated from the region between the fabric and the mould surface, for example through ducts in the mould tool leading from the mould surface to create a partial vacuum which draws the fabric into close contact with the mould surface.

(x) adhesives can be applied (e.g. sprayed) onto the mould surface or the fabric to hold the fabric in place during laying-up. Advantageously, the adhesive is volatile (of low molecular weight) so that the adhesive evaporates at say 50°C, effectively disappearing during the elevated temperature of moulding. A similar technique can be used to attach one fabric layer to another.

Handling of the composite material may be eased by calendering a sheet to part-consolidate and stiffen it. With a suitable heating and pressing operation, this sheet can be pressed or stamped like a sheet of metal into a desired shape.

During the melt phase, thermoplastics readily oxidise and so may degrade if held above their melt temperature for too long. Precise control of heating is therefore required; the invention contemplates hot gas, conduction, induction, and infra-red. Where infra-red heating is employed, short-wave infra-red radiation is preferred as this gives a faster heating response than medium- or long-wave infra-red radiation.

As it is wasteful and slow to heat a bulky mould tool and as wholly heat-resistant mould tools are expensive, the invention contemplates means for applying heat directly to the thermoplastic composite material, for example by applying heater mats to the material or by incorporating radiation-absorbent fillers in the material which heat up under radiation. The fillers may respond to infra-red, microwave or radio frequency heating. Induction heating is possible for composite materials of a suitable nature, such as those reinforced by carbon fibre.

Possible fillers include:

carbon black, which assists thermal conductivity for radiation heating, absorbs infra-red radiation, and enhances anti-static properties;

intumescent fillers, which enhance fire resistance by expanding and charring to insulate the material;

aluminium trihydrate, which decomposes to aluminium oxide under heating and gives off water to absorb heat; and

chlorides and bromides which form HCl and HBr in a fire, helping to extinguish the fire.

To consolidate the molten thermoplastic filaments and thus to ensure that the molten thermoplastic thoroughly impregnates the fibre reinforcement, the invention contemplates techniques which apply controlled pressure to the material in the mould. These techniques include: hydroforming; matched metal dies; a simple vacuum bag, which operates at 1 bar; a rubber male mould which expands thermally during the process, exerting 1 to 10 bar but without accurate control; a hydraulically-pressurised rubber diaphragm, exerting 1 to 5 bar; and an autoclave, exerting 1 to 20 bar.

A mould tool for use in the process of the invention may be made from any suitable heat-resistant material, such as high-temperature fibre-reinforced epoxy composites, ceramics, or metal. However, if heat is applied locally (either directly to or in the region

of the thermoplastic material) rather than by simply placing the entire mould tool in an oven or autoclave, only the moulding surface region of the mould tool need be of heat-resistant material: the bulk of the mould tool can be of conventional low-cost materials like g.r.p. (glass-fibre reinforced plastics)

The invention can employ various commercially-available thermoplastic composite materials. Examples are:

1. An interdispersed product from BASF, comprising carbon fibres and polymer filaments (e.g. polyetheretherketone or PEEK) which lie in alignment in each yarn, with approximately 65% reinforcement and 35% polymer matrix expressed by volume. BASF also supplied carbon fibre coated with a solution of polysulphone or polyethersulphone.

2. A non-crimp fabric 'Thermopreg' (Trade Mark) from Tech Textiles Limited, comprising layers of different yarns which layers overlie each other and may include differently-aligned reinforcement layers to give multi-directional properties.

3. Powder-coated 'FIT' materials from e.g. Ciba-Geigy or Atochem, in which a powder polymer such as nylon 6, 11 or 12 is coated onto glass filaments either electrostatically or by a fluidised bed process and a thin layer of polymer, such as polyamide, is co-extruded over the filaments.

4. 'Prepreg' tapes in which fibres pulled through a cross-head extruder are coated with polymer to form a tape.

5. 'Azdel' (Trade Mark), a rigid sheet manufactured by extruding a polymeric sheet and sprinkling long reinforcing fibres onto the sheet with random orientation.

Proprietary pre-preg tapes or fabrics (co-mingled or interdispersed), non-crimp fabrics or woven fabrics can have various volumetric ratios between fibre reinforcements and thermoplastic filaments, as required for different tasks.

It is preferred that the thermoplastic composite material contains polypropylene or polyethylene filaments to form the polymer matrix, as these materials are inexpensive and melt at a sufficiently low temperature - between 130°C and 220°C - to allow the use of a composite mould tool. Nylon-based materials can also be used but, as nylon melts at around 260°C, necessitate non-composite (e.g. metal) mould tools. Various other polymers, such as polyethyleneterephthalate (PET) can be used, subject to melting point, creep resistance, cost and other parameters.

The finished component may be self-coloured or may bear a layer of paint or other coating such as an anti-fouling coating for boat hulls, which may be sprayed or welded in place. For secure bonding of this layer or coating, the surface of the component may require activation by flame treatments, roughening or cryogenic cleaning to remove release agents.

The fabric layer or layers immediately adjacent to the mould tool can have a reduced reinforcement content or, indeed, there may be no reinforcement at all in that region leaving a layer rich in thermoplastic polymer at the surface of the finished component. A similar layer could be formed by use of non-reinforced plain sheet material as opposed to a fabric. This layer gives a resin finish as may be required for protection of the component from the environment or for aesthetic reasons.

Copper filaments or fillers can be incorporated in surface layers of the composite lay-up to discourage fouling of boat hulls. More generally, metal filaments can be incorporated in the component during moulding to disperse static electricity, to resist lightning strikes or to obtain desired EMI/RFI characteristics.

In order that this invention may be more readily understood, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a schematic cross-sectional view of a mould tool having thermoplastic composites laid-up therein and ready for moulding;

Figure 2 is a schematic cross-sectional view of a mould tool shaped to form a boat hull;

Figure 3 is a schematic cross-sectional view of a mould tool in which hot gas heats the composite material during moulding;

Figure 4 is a schematic cross-sectional view of a mould tool illustrating means for holding sheets of the composite material in place during lay-up; and

Figure 5 is a schematic cross-sectional view of a mould tool in which a thermally-expandable silicone rubber insert exerts pressure on a lay-up in the mould tool.

Referring to Figure 1 of the drawings, a mould tool 10 defines a polished mould surface 12. The mould surface 12 is coated with a proprietary release agent or is lined with proprietary adhesively-bonded PTFE release fabrics; whichever is used must, of course, be capable of withstanding the elevated temperatures used in moulding.

Thermoplastic composite layers 14 are laid-up on the mould surface 12, being positioned and oriented as desired having regard to the shape of the component and its desired properties including directional characteristics. The number of layers or plies may be varied to allow localised variations in thickness; numerous other variations can be made in desired areas, such as the type of reinforcement, fibre orientations, and the volume fraction of reinforcements.

Although the reinforcements can be varied at will, such that carbon, glass and aramid could theoretically all be used at different locations in a single component or structure, the thermoplastic matrix should be the same throughout.

Sheets of thermoplastic composite material can be placed side-by-side to cover large areas. They can be cut and overlapped (generally by at least 50 mm) or the abutting joint can be overlaid by a further sheet of composite material.

Stiffening features such as ribs and stringers can be moulded in using honeycomb, foam

or wooden cores sandwiched by thermoplastic composite sheets. Alternatively, these structures can be fabricated separately and attached to the composite component thereafter using any known fastening, bonding or welding technique.

Similarly, inserts of metal, composite or other material can be moulded in to the laminate or attached subsequently to provide mechanical fixing points in the finished component, or to strengthen regions of the component.

When the various composite layers, cores and inserts have been assembled to form a lay-up, a release film 16 is laid down over the lay-up and is held in place with adhesive tape.

If higher moulding pressure is required in certain regions, caul plates of metal, composite, polymer or ceramics can be rested on the release film.

A porous breather fabric 18 is laid on top of the release film and either proprietary bagging films or pre-shaped reusable rubber (e.g. silicone rubber) sheets 20 are laid over the breather fabric and sealed to the mould tool using e.g. silicone sealants to form a vacuum bag.

At the start of the moulding process, air is withdrawn from the vacuum bag using a vacuum pump 22 acting through a non-return valve 24, thus applying a uniform pressure of about one bar to the lay-up within. A vacuum gauge 26 is employed to monitor this pressure precisely.

Figure 2 corresponds generally to Figure 1, so like features are identified by like reference numerals. This shows a deep V-section mould 28 required to produce a boat hull. In this case, sheets 30 of thermoplastic composite are draped from each side of the mould, each sheet 30 being fixed to the mould at its upper end by a clamp 32 and being overlapped at its lower end with the corresponding sheet 30 on the other side of the mould 28. The overlaps are staggered as shown, and a caul plate 34 exerts extra pressure on the overlapped region. Further, a stiffening insert 36 is moulded in at the

keel.

If the size of the mould tool permits, the tool is placed in an oven or an autoclave and is heated to a moulding temperature while pressure is maintained via the vacuum bag. The moulding temperature is the melting temperature of the thermoplastic matrix (180°C-220°C for polypropylene and 250°C-280°C for nylons). However, should the mould tool 28 be too large for available ovens or autoclaves, the mould tool can be insulated using surrounding insulating panels 38 as shown in Figure 3 and hot gas introduced from e.g. a gas-fired heater (not shown). Hot gas heating may be supplemented by heater belts 40 adjacent the mould surface.

The temperature of the lay-up and its surroundings is clearly crucial and so requires close monitoring. To this end, thermocouples may be incorporated at key locations in the lay-up, for example to measure air, moulding surface and lay-up temperatures.

Once all parts of the lay-up have reached the moulding temperature, that temperature must be sustained for a holding period to ensure that all of the thermoplastic filaments have melted and flowed together to form a homogeneous structure. We have found that a holding period of twenty minutes is appropriate for polypropylene-based composites at a pressure of one bar and at 180°C-220°C.

As temperature or pressure are increased to promote the flow of molten plastics through the lay-up, the holding period can be reduced: we have found that increasing the pressure to six bars (using the vacuum bag in an autoclave pressurised to five bars) reduces the period to just three minutes. It is estimated that if a pressure of 30 bars is exerted at a moulding temperature of 220°C (this being the upper end of the moulding temperature range for polypropylene), the holding period could be as little as 10 to 15 seconds.

At the end of the holding period, the mould tool is allowed to cool and the various layers are disassembled to release the moulded structure for finishing.

Figure 4 illustrates a mould tool 42 adapted to hold composite sheets in place during lay-up, before the vacuum bag comes into play. For this purpose, retractable pins 44 extend through the mould surface to engage composites laid up therein. The pins 44 are shown extended but, when the vacuum bag is evacuated, may be retracted by means such as hydraulic or pneumatic actuators, solenoids or mechanical linkages.

The mould tool 42 also illustrates tensioned rollers 46 situated at the upper side edges of the mould tool. The rollers 46 are biased downwardly to act on a composite sheet so that the composite sheet can slump downwardly into the mould tool 42 under tension, without wrinkling.

Pressure may be applied by means other than vacuum bags or autoclaves. Figure 5 illustrates a mould tool 48 in which a lay-up 50 is compressed by a silicone rubber insert 52. To exert the requisite pressure, the insert 52 could be pressed into the mould tool 48 but it is preferred simply to use thermal expansion of the insert 52 by placing the mould tool in an oven.

Other variations are possible without departing from the inventive concept. For example, pressure can be applied by hydroforming, rubber block moulding, diaphragm forming or matched dies.

It is also possible to mould non-reinforced materials using the methods of this invention. For example, a fabric woven, knitted or braided from polymer filaments or yarns can be inserted in a mould tool in plain sheets or pre-shaped. The fabric is heated in the mould tool under pressure to its melt temperature, causing the filaments or yarns to melt completely to achieve the desired shape and finish as determined by the mould.

It is envisaged that this method could be used instead of vacuum forming of thermoplastic sheet or rotational moulding of granule materials currently used to make items such as traffic cones, bollards and so on.

Indeed, the present invention may be embodied in many other specific forms without

departing from its essential attributes. Accordingly, reference should be made to the appended claims and general statements herein rather than to the foregoing specific description as indicating the scope of the invention.

CLAIMS

1. A method of moulding a product, comprising laying-up a thermoplastic composite fabric in a mould, applying pressure to the lay-up and maintaining pressure on the lay-up during: heating the lay-up to over the melting temperature of the thermoplastic; holding the lay-up for a holding period over the melting temperature; and cooling the lay-up to solidify the thermoplastic.

2. A method according to claim 1, wherein the thermoplastic composite fabric is fibre reinforced.

3. A method according to claim 1 or claim 2, wherein pressure is applied by a vacuum bag.

4. A method according to any preceding claim, wherein pressure is applied by an autoclave.

5. A method according to claim 1 or claim 2, wherein the mould is female and pressure is applied by thermal expansion of a male mould insert.

6. A method according to claim 1 or claim 2, wherein pressure is applied by hydroforming, rubber block moulding, diaphragm forming or matched dies.

7. A method according to any preceding claim, wherein pressure is increased while the lay-up is over the melting temperature of the thermoplastic.

8. A method according to any preceding claim, wherein heating is confined to the lay-up or to the region of the mould tool adjacent the lay-up.

9. A method according to claim 8, wherein heating is effected by radio frequency, microwave or infra red emitters.

10. A method according to claim 9, wherein the thermoplastic composite contains radiation-absorbing fillers.

11. A method according to claim 8, wherein heating is effected by induction heaters.

12. A method according to any preceding claim, comprising supporting the thermoplastic fabric within the mould tool before the pressure is applied.

13. A method according to claim 12, wherein support is provided by clamp means acting on the fabric.

14. A method according to claim 13, wherein the clamp means is situated on an upper side edge of the mould and acts on an edge of the fabric, the remainder of the fabric hanging into the mould.

15. A method according to claim 14, wherein the fabric hanging into the mould from one side is overlapped with fabric hanging into the mould from the other side.

16. A method according to claim 12, wherein support is provided by adhesive means.

17. A method according to claim 16, wherein the adhesive means is a layer of adhesive applied to the mould tool or to the fabric.

18. A method according to claim 17, wherein the adhesive evaporates below the melting temperature of the thermoplastic.

19. A method according to claim 12, wherein the fabric is locally heated to tack it to the mould tool.

20. A method according to claim 19, wherein polymer powder is applied to the fabric before tacking.

21. A method according to claim 12, comprising applying a vacuum to the fabric through the moulding surface of the mould tool.

22. A method according to claim 12, comprising electrostatically charging the mould tool or the fabric.

23. A method according to claim 12, comprising engaging the fabric with at least one pin.

24. A method according to claim 23, wherein the pin is retracted into the mould surface after the pressure is applied.

25. A method according to claim 23, wherein the pin is moulded in to the thermoplastic product.

26. A method according to any preceding claim, comprising incorporating metallic filaments or fillers into the lay-up.

27. A method according to claim 3 or to any of claims 4 to 26 when appendant to claim 3, comprising increasing the ratio of matrix to reinforcement in the region of the lay-up adjacent the tool.

28. A method according to any preceding claim, wherein the thermoplastic fabric is woven, knitted or braided from thermoplastic filaments or yarns.

29. A method according to any preceding claim, wherein the holding period is up to twenty minutes and the pressure is in the range 1 to 30 bar.

30. A method of moulding a product, substantially as hereinbefore described with reference to or as illustrated in any of the accompanying drawings.

31. A mould tool adapted for use in the method of any preceding claim.

32. A thermoplastic moulded product produced by the method of any of claims 1 to 30.

33. A thermoplastic moulded product according to claim 32, being a large surface area open-mould structure such as a boat hull or a marine structure.

34. A thermoplastic moulded product according to claim 33, and including copper filaments or fillers in its surface regions.

Application No: GB 9704535.5
Claims searched: 1-34

Examiner: Monty Siddique
Date of search: 27 May 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): B5A (AT1P); B5N

Int Cl (Ed.6): B29C 43/12 43/20 43/52 43/56 51/08 51/14 51/18 70/30

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 1570000	(NRDC) page 1 lines 14-69; page 2 lines 6-11; example 1 etc.	1 at least
X	GB 1323592	(ANVER) page 2 lines 106-125; page 3 lines 75-94 etc.	1 at least
X	GB 1297197	(BADISCHE...) page 3 lines 48-87; page 4 lines 44-51 etc.	1 at least
X	GB 1171349	(RUDLOFF) page 1 lines 49-67; page 2 lines 3-13	1 at least
X	EP 0257466 A2	(GEC) entire document and column 28 lines 7-43 etc.	1 at least
X	EP 0201029 A2	(BAYER)	1 at least
X	WO 9416870 A1	(DU PONT...) page 4 lines 14-33 etc.	1 at least
X	US 4906172	(SHELL) column 1 paragraph 2; column 2 lines 35-43 etc.	1 at least
X	US 3886248	(NICHOLSON) entire document	1 at least

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The Patent Office

Application No: GB 9704535.5
Claims searched: 1-34

Examiner: Monty Siddique
Date of search: 27 May 1997

Category	Identity of document and relevant passage	Relevant to claims
X	WPI Abstract Accession No. 85-200770 & JP 60127148A (MATSUSHITA) 06.07.85 (see abstract)	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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